Performance demands in the Endurance Rider

Williams, J.M.[1], Douglas, J.[1], Davies, E.[1], Bloom,F.[1] and Castejon, C.[2]*

[2]. Hartpury University, Gloucester, GL19 3BE, UK.
[1] Cordoba University, Cordoba, Spain

*Corresponding author: jane.williams@hartpury.ac.uk

Abstract

Endurance is one of the fastest growing equestrian disciplines worldwide. Races are long distance competitions (40-160km), organized into loops, over variable terrain usually within one day. Horse and rider combinations in endurance races have to complete the course in good condition whilst also aiming to win. Horse welfare is paramount within the sport and horses are required to ‘pass’ a veterinary check prior to racing, after each loop of the course and at the end of the race. Despite the health, fitness and welfare of both athletes within the horse-rider dyad being essential to achieve success, few equivalent measures assessing the wellbeing of the endurance rider are implemented. This review considers evidence from ultra-endurance sports and rider performance in other equestrian disciplines, to consider physiological and psychological strategies the endurance rider could use to enhance their competition performance. Successful endurance riding requires an effective partnership to be established between horse and rider. Within this partnership, adequate rider health and fitness are key to optimal decision-making to manage the horse effectively during training and competition, but just as importantly riders should manage themselves as an athlete. Targeted management for superior rider performance can underpin more effective decision-making promoting ethical equitation practices and optimizing competition performance. Therefore the responsible and competitive endurance rider needs to consider how they prepare themselves adequately for participation in the sport. This should include engaging in appropriate physiological training for fitness and musculoskeletal strength and conditioning. Alongside planning nutritional strategies to support rider performance in training and within the pre-, peri- and post-competition periods to promote superior physical and cognitive performance, and prevent injury. By applying an evidence informed approach to self-management, the endurance athlete will support the horse and rider partnership to achieve to their optimal capacity, whilst maximizing both parties physical and psychological wellbeing.

Keywords:

Endurance racing; equestrian sport; performance analysis; ultra-endurance; endurance horse

Introduction

Endurance riding is popular worldwide. The sport is governed by the Fédération Équestre Internationalé (FEI) and is reported to be one of the fastest growing equestrian disciplines (Bennett and Parkin, 2018; Marlin and Williams, 2018a), with a 68% increase in FEI registered endurance riders since 2007 (FEI Endurance Report, 2017). Research within endurance has predominately focused on determining factors which impact endurance horse health, management and welfare; however to be successful, the wellbeing of both partners in the horse-rider dyad should be understood. At elite level in any sport the difference between winning and losing can be attributed to differences in the physiological or psychological status of the athletes participating in it, unforced errors from participants, efficacy of training regimens or variance within associated equipment (Williams, 2013; Woodman and Hardy, 2003; Williams and Ericsson, 2005). One method to prevent failure and maximize success is to integrate performance analysis into the review of training and competition practices (Hughes and Bartlett, 2002). Performance analysis is the systematic observation and analysis of factors identified to enhance athlete and / or team performance in the context of a specific sport, with the aim to improve athlete decision-making, in both training and competition, to facilitate increased competitive success (McGarry, 2009; Williams, 2013). Within equestrian sport, it is critical for success that any performance analysis techniques applied consider the horse, the rider, and the horse and rider partnership as separate but interconnected entities (Williams 2013, Williams and Tabor, 2017). Therefore, the aim of this review is to evaluate the physiological, nutritional and psychological performance demands on the endurance rider as an athlete. Evidence from ultra-endurance sports and rider performance in other equestrian disciplines, will be used to identify potential training and competition strategies, which could improve individual performance, and by association enhance the welfare and competitive success of their equine partner.

What is equestrian endurance racing?

Endurance is a long-distance competition for horse and rider combinations against the clock, usually within one day. Competitions, colloquially known as races, test the fitness and endurance of the horse, and challenge the rider to effectively manage their horse's pacing strategy across variable terrain, with the aim of the horse completing in good condition within an optimal time (graded races) or within a traditional race format (FEI, 2020a). Globally, race distances vary between 40km to 160km, with most beginner events racing over 40 and 60 km, progressing to 80, 120 and 160 km for advanced and international level competition. At international level, individual and team competitions are also categorized according to the level of difficulty they represent (Tables 1 and 2); furthermore to be eligible to compete, horse and rider combinations need to meet strict qualifying criteria (Table 3). Mandatory out of competition periods (MOOCPs) also apply to horses at the international level of the sport and can limit participation in races (Table 4); currently no equivalent MOOCP apply for riders.

In 2017, 930 international races took place, across 52 countries and a total of 7142 riders and 14949 horses were registered with the FEI (FEI Endurance Report, 2017). Races occur across the globe in variable climates, therefore the effects of temperature and humidity can influence both horse and rider performance during races (Marlin and Williams, 2018a). Managing equine welfare within endurance riding is a key strategic consideration of the FEI; however the majority of research and monitoring during competitions focuses on the horse, and how the rider (and their wider team) are optimizing equine health and welfare. Races consist of a number of phases or loops; each of which may not exceed 40 km and should not be less than 16 km. At the end of each loop, there is a compulsory stop (known as the vet gate) for the horse to undergo a veterinary inspection, which it must pass to be able to continue racing. However, despite the health, fitness and welfare of both athletes within the horse-rider dyad being essential to achieve success in endurance riding, there are no equivalent checks in place for the rider. The 2020 FEI endurance rulebook states "*participation in competition must be restricted to fit Horses and Athletes* (defined as the person who rides the horse in competition) *of proven competence*" and encourages all those involved in equestrian sport to attain the highest levels of education and expertise in the care and management of the equine athlete (FEI, 2020a).

Horse welfare is the key priority within endurance, reflecting the responsibility and duty of care riders, trainers, event organizers and equestrian federations have to protect the equine athletes who cannot articulate if their health or welfare is compromised (Williams and Tabor, 2017). Riders can participate in endurance as an athlete from the 1st of January in the year they reach 14 years of age (FEI, 2020a). Male and female riders are treated equally as athletes and have a personal and non-delegable responsibility to familiarize themselves with the FEI Rules and Regulations. Riders must comply with minimum weight requirements when competing in FEI endurance competitions (Table 5); however there are no formalized maximum weights for riders in FEI competition and the ratio of rider: horse weight is not measured (FEI, 2020a). Event organizers provide a reliable, calibrated weighing machine that is used for athlete weight control checks before the start (mandatory) and the end (by request of an FEI official) of the competition. Athletes should maintain their minimum riding weight throughout the competition regardless of if they are riding or leading the horse, and random weight control inspections can occur at any time if requested by an FEI official (FEI, 2020). Failing to meet minimum weight requirements or to undertake a weight control check, results in the combination being disqualified (FEI, 2020a). Riders are also required to concur with anti-doping regulations and to declare if they are taking any medication that may enhance performance (FEI, 2020a). During racing, the ground jury are also authorized to stop a rider if they believe they are unfit to continue to race, but there are no compulsory rider health or welfare checks that take place after each loop or at the end of the race (FEI, 2020a).

Table 1: Fédération Équestre Internationalé (FEI) categories of starred level endurance rides (FEI 2020a); Concours de Raid d'Endurance International (CEI); Concours de Raid d'Endurance International Officiel (CEIO).

Star levels	CEIs, CEIOs and Championships are also usually divided into three star levels (with 3* being the highest level): 1*: Competitions between 100-119 km in one day; minimum of three loops, 2*: Competitions between 120-139 km in one day, or between 7089 km per day over two days; minimum of four loops, 3*: Competitions between 140-160 km in one day, or 90-100 km per day over two days, or 70-80 km per day over three days or more; minimum of five loops, 3* Championship 160km in one day, minimum of six loops.

Table 2. Fédération Équestre Internationalé (FEI) categories of endurance rides in accordance with the FEI 2020 Endurance Rules (effective from July 2020) (FEI, 2020a). The rulebook is available at: https://inside.fei.org/fei/disc/endurance/rules

Competition Level	**Key criteria for FEI international competitions**
Concours de Raid d'Endurance International (CEI)	To participate combinations require official individual classification No official team classification criteria in place The organizing committee can permit athletes to compete in a team of 3 to 5, not necessarily of the same nationality
Concours de Raid d'Endurance International Officiel (CEIO)	To participate combinations require official individual classification and an official team classification for team competition Each nation may enter only one team in the team competition A minimum of 3 teams are necessary for a team competition to be considered an official team competition Each team must have a minimum of three combinations and a maximum of five combinations
Championships (including test events for Championships) and Games	To participate combinations must have an official individual classification and an official team classification for team competition (except for Young Horse Championships) Each nation may enter only one team in the team competition A minimum of 3 teams are necessary for a team competition to be considered an official team competition Each team consists of a minimum of three combinations and a maximum of five combinations 1* Championships must be a minimum of 100 km and a maximum of 119km in length, in one day 2* Young Horse Championships must be a minimum of 120 km and a maximum of 130 km, in one day 2* Junior and Young Rider Championships must be a minimum of 120 km and maximum of 130 km, in one day 2* Senior Championships must be a minimum of 120 km and maximum of 139 km, in one day 3* Senior Championships must be 160 km, in one day Championships at the Senior or Junior/Young Rider level may be organized on a regional, continental or world level, or as games

Table 3: Factors that determine eligibility to compete in FEI endurance races (FEI, 2020)

Qualification criteria to determine horse and rider eligibility to compete
Once an athlete or horse complete an event at the CEI level qualification they are permitted to compete at that level.
CEI star ratings are valid for athletes (riders) for 5 years and for horses for 2 years.
If either horse or rider fail to complete an event at the chosen level, then they will automatically drop down one level of qualification and must complete a competition at the lower level to regain their qualification status to be eligible to compete at the higher level which they had previously failed to

complete e.g. if a horse and rider combination did not complete a 2 star race they would need to complete a 1 star race before being able to enter another 2 star race.

Table 4: Criteria for mandatory out of competition periods (MOOCPs) applied to horses participating in international endurance competitions

Mandatory out of competition periods (MOOCP)
MOOCPs apply to horses and are mandatory: a) after competing in a national event or FEI event, b) which exceed an average of >20km/hr over the loops of a race, c) record multiple metabolic eliminations, and, d) incur a serious musculoskeletal or metabolic injury within a rolling year period. NOTE: MOOOPs do not exist for riders

Rider safety is a key consideration of event organizing committees and officials are allowed to provide assistance if the athlete falls off or is separated from their horse, although this does not equate to mandatory retirement from the race or require a subsequent mandatory out of competition period to be completed. Riders are also allowed to use mobile phones and GPS devices during the race. Athlete support during the events is provided at designated areas on the course known as crew points. At these points, the rider's support team (or crew) can provide the rider with water and food, although anecdotally often riders will wait until the veterinary hold areas until eating. Crew points are required to be at least 5km apart. The FEI provide more general human athlete support via their 'Athlete Toolkit', which is applicable to riders across all FEI equestrian disciplines. The toolkit provides advice on clean sport and includes recommendations on how to stay healthy when competing, guidance on recognizing concussion, safe horse handling and recommended PPE, as well as covering sports psychology and mental training techniques (FEI, 2020b). However no specific guidance for equestrian athletes on how to manage their fitness, or dietary and hydration management are currently included in the toolkit.

Table 5: FEI minimum athlete (rider) weight requirements for endurance (FEI, 2020a)

Event	**Minimum weight**
Young Rider / Junior competitions and championships	60 kg unless competing in senior competitions when senior weights apply
Senior: Concours de Raid d'Endurance International (CEI) 1* and 2*	70 kg
Senior: Concours de Raid d'Endurance International (CEI) 3*	75 kg
Senior: Concours de Raid d'Endurance International (CEIO) and Championships	75 kg

Performance demands on the endurance rider

To participate effectively in an endurance competition, both horses and athletes (riders) must be physically fit. To date research in endurance riding has largely focused on determining the performance demands on the equine athlete (for example: Fraipont et al., 2012; Castejón-Riber, 2014), with limited evaluation of the performance demands experienced by the endurance rider during competition, or identification of key performance characteristics in the successful endurance rider. Riding strategies have been investigated: for example Viry et al. (2013; 2015) analyzed gait selection across horse and rider dyads within competition, and Marlin and Williams (2018a, b) examined the relationship between rider self-selected pacing strategies on completion and elimination rates in international endurance races. These studies indicate how rider actions and decision-making can influence equine welfare and performance, and highlight the importance within equestrian sport of considering the directorial impact of the human athlete within the horse-rider dyad (Williams and Tabor, 2017).

The performance demands of endurance riding are multifaceted and will differ according to horse, race and environmental factors (Figure 1). The successful endurance rider requires sufficient physiological and psychological fitness to remain in balance, prevent fatigue and retain the ability to assimilate relevant visual and physical information to inform effective decision-making, and execute appropriate riding strategies to optimize the performance of their equine partner (Williams, 2013). However to date, the lack of evidence-based research into rider performance in endurance is self-limiting and has wider impacts on the development of endurance riding as a sport. As a result, the demands of endurance riding are currently speculative and whilst the application of evidence from comparative ultra-endurance disciplines can be used to postulate and underpin effective training and competition strategies, discipline specific studies are required to progress the development of the rider as an athlete in the endurance.

Physiological Demand of Endurance Riding

To date, attention regarding the physiological response of the rider in endurance riding mirrors the limited focus on the rider across all equestrian sports and the actual physiologic demands of endurance riding are not yet documented. There has been emerging research that investigates responses to horse riding including measures such as heart rate, oxygen uptake, blood lactate across different equine gaits within variable riding positions in both simulated: horse simulator and live horse within training, and live ridden competitive situations (Westerling et al. 1983; Trowbridge et al. 1995; Devienne and Guzennec 2000; Perciavalle et al. 2014; Beale et al. 2015; Cullen et al. 2015; Sainas et al. 2016; Douglas et al. 2017) which can be applied to the context of endurance riding.

Endurance riding is a broad discipline with variable race distances up to 160km and thus the physiological responses are likely to be affected by the duration of the event and the riding positions adopted by the rider. In endurance riding, the rider aims to minimize the metabolic cost to themselves and the horse by managing gait and speed to optimize the horse's functional health status (Viry et al. 2015), although this has not been studied in riders in a physiological capacity to date. Endurance riders will adopt different riding positions throughout a race, shifting between 2 point and 3 point seat (Figure 2a and 2b, respectively) in trot and canter, but often spending more time in 2 point positions (Viry et al., 2013). Strategies riders select to accommodate the horse's motion at trot (e.g. rising, 2 point seat or 3 point seat 'sitting' to the gait), can influence energy expenditure, with riders shown to expend more energy in rising trot compared to sitting or 2 point seat upon a riding simulator (De Cocq et al., 2013). In the two point seat the rider's weight is borne by the stirrups without any contact of the rider's seat with the saddle; this results in the riders body experiencing reduced amplitude vertical and longitudinal displacements (Clayton and Hobbs, 2017). Canter is often easier to sit to for the rider due to the smaller longitudinal accelerations and decelerations within this gait, which makes it easier for the rider to coordinate their movements with the horse (Terada, 2000; Clayton and Hobbs, 2017). Though research is sparse, early work indicates that rider positions requiring more weight bearing from the rider, such as a 2-point seat, increases physiological demand due to degree of muscular activity required to coordinate movements of the rider's legs, arms and trunk (Clayton and Hobbs, 2017). To date research has documented that heart rate and blood lactate responses of the rider increase with the horses gait and markedly increase in canter and where jumping efforts are concerned (Westerling et al. 1983; Trowbridge et al. 1995; Devienne and Guzennec 2000; Cullen et al. 2015; Douglas et al. 2017). The increased physiological demand associated with changes in rider positions was reported to be matched by increased calorie consumption and thus metabolic cost during activities (Sung et al. 2015). Equestrian disciplines that require a rapid change in pace and direction such as cutting and reining report increased energy expenditure (metabolic equivalents of task, MET) during reining and cutting, compared to walk, trot and canter protocols. The authors' state that MET was also higher during trot and canter when compared to walking only tasks (Sung et al. 2015).

Although metabolically costly to the rider (Westerling 1983; Devienne and Guzennec 2000; Trowbridge et al. 1995; Roberts et al. 2009; Perciavalle et al. 2014; Beale et al. 2015; Sainas et al. 2016), the 2-point seat benefits equine welfare and performance by reducing loading on the horses back, compared to the 3 point seat where the rider spends more time in contact with the saddle and thus if the rider is conditioned appropriately can be an effective dyad strategy to improve performance and welfare.

A third riding style 'the desert seat' is becoming increasingly popular in endurance riders (Viry et al., 2014); anecdotally this position is reported to be more comfortable for male riders. The desert seat is essentially an adapted 3 point seat; however the rider uses a more minimalist and lightweight saddle combined with longer stirrup length and sits with the feet placed more forward than in standard endurance equitation, and the upper body set farther back, which is thought to facilitate a high degree of mobility in the pelvis (Lesté-Laserra, 2017). Clayton and Hobbs (2017) suggest elite riders can control their movements to increase synchronicity with the horse's movements, improving their consistency. Initial biomechanical evaluation of the desert seat within a 130km race reports improved quality of horse-rider coupling in seated canter, with vertical horse and rider displacements more in phase resulting in a reduced physiological load to the rider compared to the traditional 3-point seat (Viry et al., 2014). The study also found that riders when using the desert seat and tack, spent approximately four times longer during racing in siting canter (>80%), horses' average speed increased by 5.6%, and horses' galloped for 30% longer than when using traditional riding approaches (Lesté-Laserra, 2017; Viry et al., 2014). While on the surface these results suggest using a desert style seat is more efficient for the rider, further studies across greater numbers are needed to confirm this. The impact on equine welfare should also be considered; Marlin et al. (2018a, b) and Bennet and Parkin (2018) have shown increased speeds in racing are associated with a higher risk of elimination and injury in endurance races. Nagy et al. (2017) reported thoracolumbar pain to be the second most common veterinary problem experienced by endurance horses and also found higher average speeds in canter were associated with an increased risk of lameness. Despite enhancing coupling between the horse and rider, the trend for spending more time in a seated gallop observed in riders adopting the desert seat could potentiate these issues and further work exploring the impact of using this riding style on both endurance rider and horse performance and welfare are warranted.

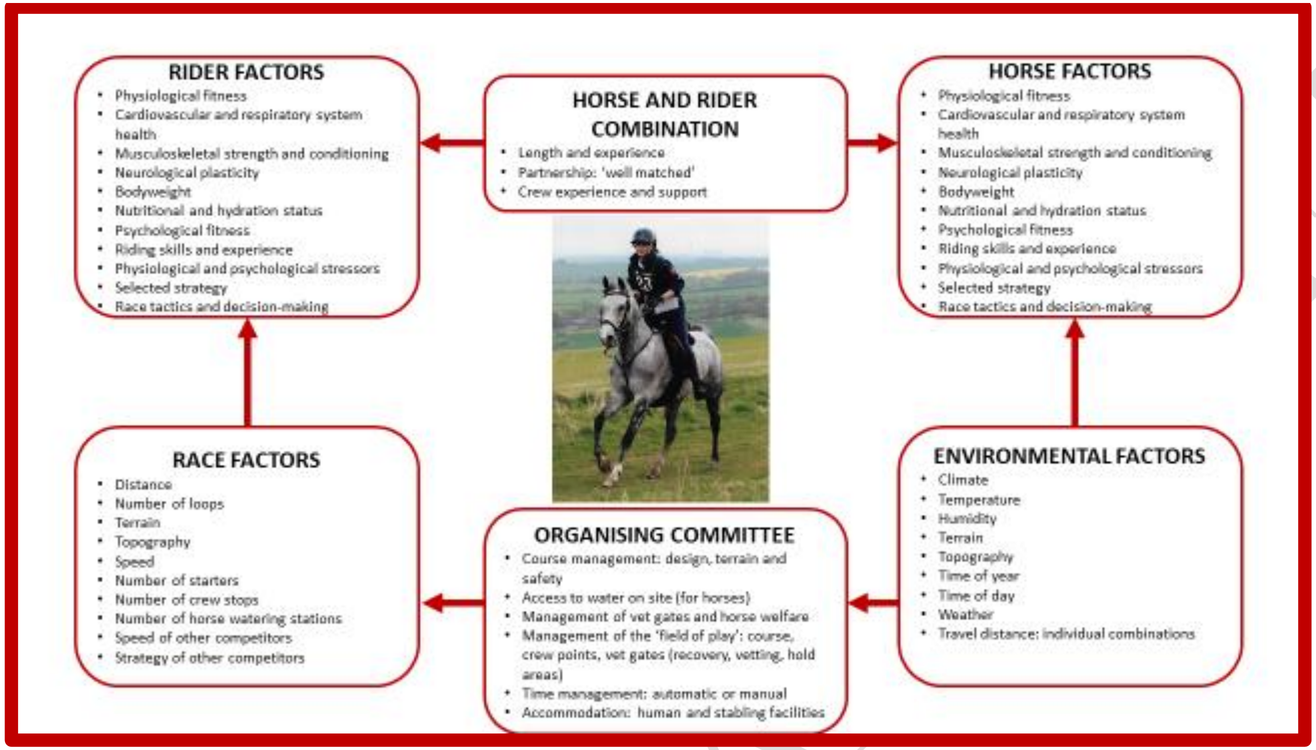

Figure 1: Factors that contribute to successful completion of endurance competitions (adapted from FEI, 2020a; Williams, 2013; Marlin and Williams, 2018a, b, Bennett and Parkin, 2018)

Cumulative research studies agree that physiological markers of exercise intensity increase as rider positions and horse gaits progress from walk, to 2-point and jumping positions. There is however early work that reports that the physiological responses to horse riding are more multifactorial and require further understanding to further understand the demands of equestrian sport on the rider. Douglas et al. (2017) reported that unlike heart rate and blood lactate, oxygen uptake data do not rise at the same rate as heart rate during horse riding activities, and in general are not representative for what is documented during dynamic exercise. In dynamic exercise, a rise in heart rate is linear to oxygen consumption and a more marked blood lactate concentration is apparent. Collective data in physiological demands of horse riding are in agreement with this finding (Westerling 1983; Devienne and Guzennec 2000; Trowbridge et al. 1995; Roberts et al. 2009; Perciavalle et al. 2014; Beale et al. 2015; Sainas et al. 2016). Douglas et al. (2017) have proposed that a dissociation between heart rate and oxygen uptake are the result of the high requirements for isometric muscle activity which stimulate a disassociation between physiological parameters as a response to increases in rider blood pressure. Therefore ultimately horse riding in a 2 point canter may elicit a high heart rate in riders, but this high heart rate may not be truly reflective of the actual physiological load or energy requirements of riding itself. A further understanding the physiological responses of horse riding and the discipline specific demands will assist practitioners to condition the riders appropriately to offset fatigue and be in a position to adapt position to best support the competitive equestrian dyad.

Ultimately, when considering the physiological demands of endurance riding on the rider, it is sensible to consider the distance and thus duration of the race, and how much time the rider spends in each riding position. The proportional use of each riding technique used in endurance riding is explained in an exploratory capacity by Viry et al. (2015). This research group highlighted in international equine endurance races of 130km, the majority of race time was spent in two point canter (34%) and rising trot (33%) followed by sitting canter (3 point seat; 21%) and 2 point trot (12%). Detailed time motion analysis matched to the physiological response of endurance racing to riding demands is necessary to further evaluate the demands placed on these (human) athletes, however, the initial data suggests that mixing predominantly a two point canter with rising trot is metabolically advantageous to both the horse and rider. The two point canter is metabolically costly to the rider, and based on current data would elevate heart rate substantially as a result of long duration isometric contractions of the thigh (Douglas et al. 2017), however periodic phases of rising trot would allow for replenishment of energy utilization and fatigue substrate dissipation facilitated by dynamic motion.

Though not well documented, there are supportive data that physiological demand differs between skill level of the athlete; for example, the senior league of Australian Football is played at a faster rate than junior league requiring superior aerobic and anaerobic capacity, speed, agility, strength and power (Burgess et al., 2012 Gray and Jenkins, 2010). Similarly differences in physiological and kinematic performance have also been reported linked to individual skill level in swimming (Pyne and Sharp, 2014; Seifert et al. 2008) and sailing (Friesenbichier et al., 2018). Sung et al. (2015) reported exercise intensity and calorific consumption to be non-significantly elevated in amateur riders compared to elites. The authors conclude that elite athletes consumed less calories for a given task and was implied that this was due to elite athletes being more rhythmically harmonized with their horse which reduced unnecessary calorie consumption, and that markers of intensity are affected by skillful control of elites. Though exciting as a discussion point and a potential direction of future research, these data should be interpreted with caution as many markers of physiological intensity were non-significantly elevated and the discussion was not supported with biomechanical investigation. It does highlight the potential for future rider performance research enquiry to consider the synchrony of the equestrian dyad and its relationship to physiological demand.

Figure 2: A) 3 point seat in canter; B) 2 point seat in canter (photos FB)

Figure 3: Example of ‘desert seat’ position (reproduced with permission)

The vacillating nature of equestrian sport and the complexities of each course and each venue being different means that the physiological demands of riding are likely to be dependent on course specifics, and as such ideal conditions are sporadic. As a sport where riders are likely training multiple horses ideally riders need to be physically conditioned to tolerate a high riding training load in addition to the demands of the actual competition, to perform optimally in competition and avoid injury.

Physical demands

There is a paucity of research concerning the physiological demands of endurance riding in general on which riders, trainers and coaches can base physical preparation strategies for endurance riders. Studies have shown that riding activities alone are insufficient to prepare equestrian athletes for the physical and physiological demands of riding and additional aerobic and strength and conditioning training regimes are required to prepare athletes for the demands of riding (Hyttinen et al., 2019; Kiely et al., 2019; Meyers, 2006). It would appear based on data concerning horse riders in general that endurance riding may evoke considerable cardiac strain; in a study examining physiological responses of horse riding, heart rate was reported as 160 beats.min-1 during Dressage competitions, 168 beats.min-1 for Show Jumping events and 177 beats,min-1 during the Cross Country phase (Douglas et al. 2017). Ultimately, heart rate responses of the rider increase with the horse's gait and markedly increase in rider positions that require a 2-point seat (Westerling et al. 1983; Trowbridge et al. 1995; Devienne and Guzennec 2000; Cullen et al. 2015).

Blood lactate concentration has previously been reported in Show Jumping (4-6.3 mmol.l/l), National Hunt racing (7 mmol.l/1) and simulated One Day Event riding (9.5 mmol.l/1), and collective research to date indicates that blood lactate concentration is greater where 2-point positions are required. Levels of blood lactate accumulation reported are above threshold levels indicating that riders adopting these positions should be conditioned to increase lactate threshold to improve performance and decrease onset of fatigue. A study by Perciavalle et al. (2014) concluded that although the concentrations of blood lactate were moderate in riders post a show jumping round, they were great enough to worsen reaction time in riders and provides further justification for endurance riders to condition themselves to off-set the early onset of blood lactate concentration.

Long durations spent in 2-point gaits during endurance riding would require an ability to tolerate sustained high heart rates and periods of peripheral fatigue of the thigh musculature and may be limiting factors for performance if not addressed with appropriate physical training. Further research to understand the physiological demands of this sport are necessary to enhance performance of the horse and rider dyad, and to facilitate evidence-based and sport-specific physical preparation strategies for riders.

Like most sports, endurance riding requires trunk flexion and extension combined with movement patterns and demands that require the body to move in a coordinated and reactive manner. As such, total body exercises (squats, deadlifts, presses, rows and pulls) should form the basis of a rider's training plan. Riders should work muscles over full ranges of motion to prevent injury in addition to sport specific movements detailed below. As a sport that requires balancing on another animal, it is considered an unstable sporting environment, as such, functional exercises that enhance neuromuscular response to an unstable environment, such as those performed on balance boards and stability boards have been proposed to be key aspects of a riders training programme. It should be noted however, that a rider should be symmetrical and functional in their land based training before moving to dynamic and unstable training methods.

Movement specific exercises should be included in an off-horse training programme, with emphasis on time under tension, isometric work and introducing periods of relief that mimic the 2-point position. Iso-ballistic exercises (e.g. isometric holds with intermittent ballistic movements) and oscillatory isometric exercises (e.g. squats with pulses) introduce the rider to movements that will improve the bodies stabilitative mechanics to changes in movement patterns observed during positional changes and changes in the terrain seen during endurance events.

In addition to sports specific training it is important that equestrians consider the asymmetric nature of an equestrian lifestyle (Symes and Ellis, 2009; Hobbs et al. 2014) and aim to improve functional strength and dynamic posture identifying muscular weakness and imbalances throughout the body in attempt to reduce the potential for injury occurrence (Lewis and Kennerly, 2017; Lewis et al. 2019). Several studies have reported the incidence of injuries in equestrians and 96% of riders have been reported to use pain medication to offset chronic pain (Lewis and Kennerly, 2017; Lewis et al. 2019) As such, riders should include injury prevention and posture based exercises that focus on increasing mobility and stability of the scapular and shoulder girdle, strengthening the posterior chain and mobilising the hip flexors to alleviate high occurrence of upper and lower back pain in riders (Lewis et al. 2018)

The competition season for Endurance varies depending on the country and hemisphere horse and rider combinations compete in, with some countries such as the United Kingdom, having a defined season predominately focused between March to October, and so optimum performance will likely be periodised for key competition dates within this period. Many professional endurance riders will compete all year round, moving between countries and hemispheres. The variability in a rider's competition schedule is therefore extremely varied, making hypothetical training plans complicated, however riders should still consider the importance of tailoring their own peak performance to key events within their competition schedule. Table 6 details a hypothetical periodised training plan for an endurance rider aiming to reach peak riding condition during July/August.

Table 6: Example periodised plan for Northern hemisphere endurance rider aiming for peak fitness during July / August

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Mesocycle	Base Fitness		Strength		Specific		Peak Fitness		Specific		Active Recovery	

During the base fitness mesocycle, aerobic power and muscular endurance should be the focus of development, achieved through total body aerobic exercise modes such as running, cycling or rowing. High repetitions of total body movements (squats, deadlift, presses, rows and pull variations and progressions) should be included. The strength mesocycle focusses on aerobic power of the rider whilst developing strength; the selection of exercises should remain similar to the base cycle but progress exercises and variation suited to the development of the athlete, with a maximum of 10-12 repetitions. From a conditioning perspective, aerobic fitness can be progressed to manipulate the energy systems working above and below aerobic threshold in an interval based training method. As a sport with an imposed weight limit, the strength and conditioning coach and endurance athlete should discuss weight making tactics with the riding coach and nutritionist to ensure employed tactics do not affect physiological or psychological performance. If planned early enough into the periodised plan, a combined exercise and nutritional strategy can be adapted to enhance a safe reduction in weight of the rider.

The goal of the specific cycle is to introduce and develop movements such as previously mentioned balance exercises and movements that replicate the demand of the sport. This phase allows the rider to perfect their stabilitative mechanics to reactions of the horse due to the varied nature of terrain, equine unpredictability, and rider positional tactics. Examples may include isometric holds with ballistic movements, squats with pulses to add concentric/eccentric muscle activity in the working muscle and plank hold variations.

This hypothetical plan provides a base, however the strength and conditioning coach should manipulate the mesocycles to address the athletes specific goals and be flexible to adapt to environmental, tactical and individual conditions by adaptation of exercise intensity and volume of land based training to maintain a desired training load.

Nutritional demands of endurance riding

An athlete's nutritional status is crucial for their performance (Thomas et al, 2016) and while rider training and diet logs are available commercially, there is a paucity of research evaluating the performance demands of the rider as an athlete. To date studies have focused on identifying the best nutritional strategies to promote optimal performance in the horses. The individual rider's aerobic fitness, weight and strength and conditioning as well as race distance and the riding style adopted during racing will influence the metabolic demands, and therefore the subsequent nutritional requirements of the endurance rider. Endurance sports are defined as sports where athletes exercise at submaximal intensity for prolonged periods of time (Segens, 2012). The endurance athlete requires a combination of muscular endurance (the ability of a muscle/s to repeatedly develop or maintain force without fatiguing) and cardiorespiratory endurance (the ability of the cardiovascular and respiratory systems to deliver blood and oxygen to enable muscle/s to perform continuous exercise) to be successful (Fink, 2010). Endurance athletes undertake training or competitions which comprise between 30 minutes and 4 hours, with athletes participating in events that last longer than this commonly known as ultra-endurance athletes (Williamson, 2016; Fink, 2010). Ultra-endurance sports can also be classified according to distance (Spenceley et al., 2017), with the literature describing runs longer than the standard marathon of 26.2 miles (Mueller, 2012); cycling over 100 miles (Linderman et al., 2003), events of duration longer than 6 hours (Zaryski and Smith, 2005); multiple distance triathlon (Kenechlet et al., 2008) and multiday races (Lahart et al., 2013) as ultra-endurance sports. Endurance riders will often train and compete for time periods analogous to those of ultra-endurance athletes in other disciplines and race distances even at lower levels are longer than those of other equestrian disciplines. Due to the duration and continuous nature of ultra-endurance sports, these athletes often attain energy expenditures of 6000 to 8000 kcals/day, therefore it is essential that nutritional strategies to support athlete performance and health are put in place to support the demands of these sports (Fink, 2010). Therefore the performance demands for ultra-endurance athletes will be applied into the endurance riding context to propose potential strategies that individual endurance riders could personalize to accommodate the demands of specific climates, competitions and athlete health and fitness status.

The nutritional considerations of ultra-endurance athletes focus on ensuring adequate caloric and nutrient intake during training, combined with adequate energy and fluid replacement during competition to maintain optimal performance (Applegate, 2010; 1991). The nutritional demands on the endurance rider may be similar to ultra-endurance athletes, who train 1-6 hours or longer daily and compete in events up to 24 hours duration (Williamson, 2016). Usually endurance riding competitions last more than 4 hours in duration, although at elite level this time will be interspersed by breaks between loops, and anecdotally endurance riders regularly train for periods longer than this. To the authors' knowledge, no studies have evaluated the nutritional strategies in endurance riders. Ultra-endurance athletes often train for several hours a day leading to chronic fatigue, weight loss and poor performance, therefore the duration, intensity, frequency and type of exercise undertaken should be considered when formulating individual's nutritional strategies. For competition, these athletes are encouraged to undertake glycogen super-compensation and eat a pre-race meal 4 hours before the start, to enhance performance (Applegate, 2010; 1991). The impact of fluid and electrolyte losses during training and competition should also be considered, and macro and micro nutrient supplementation is often recommended for these athletes (Applegate, 2010).

Adequate energy intake is essential for optimal performance. Professional endurance riders may train more than one horse every day of the week, some days they may train more than 4 hours, while other amateur endurance riders may ride just 2-3 days per week. To assess caloric adequacy during training, endurance riders should record and monitor body weight (after voiding) weekly (at the same time each week) and ensuring they are adequately hydrated prior to being weighed to prevent fluctuating fluid losses influencing the results (Casa et al., 2000; Applegate, 1991). The schedule of these athletes may also limit opportunities for eating, which may be combined with reduced appetites due to heavy and prolonged training, limiting energy intake or athletes trying to take on board a heavy caloric load in a short time frame. In ultra-endurance athletes, the caloric cost of training has been reported as ranging from 180 to 400 kJ or 150 to 400% more energy than their sedentary peers (Applegate, 1991). Carbohydrate is the preferred fuel source when exercise intensity is greater than 65% of an athlete's VO_{2max}, however in ultra-endurance training, exercise intensity tends to decrease as duration increases, therefore both fat and carbohydrate intake should be considered to retain a positive nutritional status. Daily carbohydrate requirements for athletes vary according to level of exercise, from 5–7 g/kg/day (1 h/day of moderate exercise), 6–10 g/kg/day (1–3 h/day of exercise), to 8–12 g/kg/day (4≥ h/day of exercise) (Vitale and Getzin, 2019).

Recent guidance for ultra-endurance athletes exercising daily for 4 to 5 hours undertaking moderate to high intensity advocate carbohydrate targets of up to 8–12 g/kg/day of Jager et al. (2017). The International Society of Sports Nutrition (ISSN) also recommends athletes should employ an 8–12 g/kg/day high carbohydrate diet to maximize glycogen stores athletes. For events lasting longer than 90 minutes, such as endurance racing, carbohydrate loading or glycogen super-compensation in the preceding 36 to 48 hours is considered to enhance performance by 2 to 3% (Jeukendrup et al., 2005; Jeukendrup, 2004). Recent studies have found that short-term high-intensity exercise (or even complete physical inactivity) followed by one day of high (10–12 g/kg/day) carbohydrate intakes can achieve the same glycogen super-compensation as traditional super-compensation strategies: carbohydrate depletion followed by high carbohydrate intake strategies. Interestingly, the former approach maintains glycogen stores (in the absence of exercise depletion) for up to three days (Jeukendrup et al., 2005; Bussau et al., 2002), providing greater flexibility for athletes with gastrointestinal (GI) intolerability or GI distress prior to competition. In the final 1–4 hours prior to the event, A further single dose of 1–4 g/kg of carbohydrate is recommended 1 to 4 hours before the event for a final top-up of liver glycogen stores, as endurance events commence in the early morning directly after the overnight fast which depletes liver glycogen (Jager et al., 2017; Vitale and Getzin, 2019). During races over 60 minutes duration, active fueling strategies are recommended to maintain carbohydrate accessibility typically for events of between 1 to 2.5 hours, 30–60 g/h is commonly recommended (Jager et al., 2017; Burke et al., 2014) in a 6–8% CHO solution (concentrations typically found in commercial sports drinks), ideally consumed every 10–15 minutes (Thomas et al., 2016). Whilst for events lasting longer than 2.5 hours, higher intakes of 60–70 g/h of carbohydrate, and up to 90 g/h if tolerable have been associated with improved ultra-endurance athlete performance Jager et al., 2017; Vitale and Getzin, 2019). However, it should be noted that studies evaluating fatigue in ultra-athletes suggest that glycogen depletion alone does not account for fatigue (Noakes, 2000; Vitale and Getzin, 2019); therefore other carbohydrate sources such as lactate utilization and alternative mechanisms, such as increased capability to oxidize fat (Burke et al., 2011), are postulated to contribute to fatigue, and should be considered when designing nutritional strategies (Vitale and Getzin, 2019).

Fat consumption increases alongside increased carbohydrate intake, and whilst specific fat supplement strategies are not required, fat stores can provide valuable energy sources. Ultra-endurance athletes often avoid high-fat foods for fear of weight gain; however high-fat foods such as peanut butter can help athletes increase their caloric intake, particularly in individuals who struggle to achieve their daily requirement. Ultra-endurance athletes are advised to follow public health guidelines to ensure they maintain an adequate fat intake, and only consider limiting fat intake pre-race during a carbohydrate loading phase or pre-race if they have GI comfort concerns (Jager et al., 2017; Vitale and Getzin, 2019). While generally sports nutrition guidelines have advised carbohydrate rich diets for athletes, the impact of a ketogenic diet on athletic performance has become the subject of much interest in recent years (McSwiney et al., 2019a). A ketogenic diet is made up of low-carbohydrate (<20–50 g/d), moderate protein and high-fat (>75–80% energy) intakes, where monounsaturated and saturated fatty acids sources are prioritized as the main dietary components (Evans et al., 2016; Phinney and Volek, 2011). This approach is associated with increased circulating levels of free fatty acids and ketone bodies (acetone, acetoacetate (AcAc) and beta-hydroxybutyrate (βHB)) similar to what is observed in a nutritional ketosis crisis (starvation) (McSwiney et al., 2019a, b). No long term performance enhancing benefits from adopting a ketogenic diet have been reported in endurance athletes; however it is important to note that a ketogenic diet did not cause a performance decrement unless athletes were competing at >70% VO_{2max} (McSwiney et al., 2019b). There are anecdotal reports of endurance riders adopting a carbohydrate-restricted dietary approach in practice and recent FEI changes to rider weight rules may facilitate these in male riders. Further work is needed to fully evaluated the impact of these types of diets on long term rider health and welfare.

Protein is also important and can be used as a fuel source, providing 5 to 15% of energy expenditure through amino acid oxidation, and a positive nitrogen balance is required to facilitate tissue repair (Vitale and Getzin, 2019). Therefore ultra-endurance athletes often have a higher protein intake (2.0 to 2.5g /kg/ day) compared to general athletes (Onywera et al., 2004). Vitale and Retzin (2019) suggest increasing protein intake on the day preceding and day of competition may have some performance benefits. They recommend a competition strategy of protein doses of 0.3 g/kg (or ~20–40 g of protein), every 3–5 h spread throughout the competition (including a dose immediately before and 0 to 2 hours post-competition) to a total of ~1.2–2.0 g/kg/day, to promote a positive nitrogen balance to benefit endurance athlete performance and recovery.

Increased dietary protein is also advocated to promote muscle hypertrophy, retain muscle mass and to facilitate tissue repair post exercise (Moore et al., 2014; Philips et al., 2011). The maintenance of muscle mass is a balance between muscle protein synthesis (MPS) and muscle protein breakdown (MPB), with the goal of retaining the body in a positive nitrogen balance (Philips et al., 2011). Prolonged, sustained endurance training results in significant metabolic demands on the athlete's body including depletion of endogenous fuel stores (e.g. liver and muscle glycogen), loss of body fluid and electrolytes, hormonal perturbations, and damage and disruption to skeletal muscle and body proteins (Moore et al., 2014). Recovery strategies for competitive athletes engaged in endurance-based training typically focus on 3 inter-related approaches: refueling, rehydration, and repair (Moore et al., 2014). Post-exercise intakes of protein occur at the optimal time to attenuate damage and promote repair by stimulating MPS (Burd et al., 2009; Philips et al., 2011; Moore et al., 2014). The dose of protein that appears to maximally stimulate MPS appears to be in the range of 20–25 g / kg, although this figure may be reduced for lighter athletes, such as endurance riders, below <85 kg (Philips et al., 2011).

The quality of protein ingested is an important factor to consider. Quality is measured by the protein digestibility corrected amino acid score or PDCAAS; higher quality proteins record a PDCAAS of 1.0 or close to 1 (Philips et al., 2011). Animal derived protein sources: milk, eggs and meat have scores are high quality and are artificially truncated at 1.0 despite the fact that isolated the actual scores of milk proteins, casein, and whey proteins are reported as ∼1.2 (Phillips et al., 2009). Soy is an alternative plant based source of high quality protein, scoring 1.0 in an isolated format (Philips et al., 2011). Habitual consumption of dairy products to promote muscle recovery and adaptation has been studied, and it appears this approach can have a beneficial impact for the athlete (Philips et al., 2011). Milk could therefore be an economical, practical, and efficacious alternative to isotonic sports drinks post exercise, particularly flavored milk that contains added simple sugar, promoting fluid retention, carbohydrate to restore muscle glycogen, and high-quality proteins to repair and facilitate adaptive changes in protein synthesis (Philips et al., 2011).

Nutritional strategies for competition centre on preparing the body for the demands of prolonged exercise and should be considered within a periodized training plan mapped to key competitive goals (Zaryski and Smith, 2004). During endurance races, riders may be in the saddle cumulatively for periods of between 7 and 10 hours for a 160km race, therefore utilizing a suitable strategy to prevent the onset of fatigue through nutritional deficits and to prevent dehydration are essential. Costa et al. (2018; 2014; 2013) have consistently reported that athletes possess an inadequate nutrition status due to factors such as the absence of nutrition education, ignoring the development of symptoms during racing e.g. appetite suppression, taste fatigue, and gastrointestinal symptoms, and practical logistical race issues such as, inadequacy of food preparation facilities, time, and/or motivation. The impact of logistical factors could be exaggerated in endurance riding, as often riders will have to deal with practical race issues, taking care of the horse and tend to prioritize the horse's nutrition and hydration status, rather than considering their own. In a trained athlete, generally carbohydrate stores amount to ~2000 calories, which can support 2 to 3 hours of exercise, depending on exercise intensity (Applegate, 1991). This is insufficient for the ultra-endurance athlete including the endurance rider who will be riding in races for longer than this. Therefore glycogen super-compensation strategies are necessary to prevent poor performance and the risks associated with this, including rider safety and poor rider decision-making resulting in negative equine welfare. Glycogen super-compensation has been documented in runners and cyclists through carbohydrate loading combined with a tapered training regime, some athletes benefit from having a meal 1 to 4 hours prior to competition (1 to 4.5g per kg bodyweight of carbohydrate) and ensuring fluid and energy intake are maintained during competition (Vitalie and Retzon, 2019; Applegate, 1991). This is the equivalent of 0.3 to 1.1g/hr of carbohydrate, or for the average carbohydrate drink (normally 5 to 10% carbohydrate) a rate of 150 to 250ml every 15 to 20 minutes (Costa et al., 2019). Recent studies also suggest the source of carbohydrate can be influential to performance, with glucose-fructose carbohydrate blends (e.g. 1:1 to 2:1 ratios) producing superior carbohydrate oxidation and performance over single blends (e.g. glucose alone) (Costa et al., 2019).

It should also be noted that there are different factors that increase energy needs above normal baseline levels which riders should consider when competing and training. These include the climate where they train and during races, exposure to cold or heat and humidity will impact on energy and fluid requirements. Furthermore, fear, stress, high altitude exposure, some physical injuries, specific drugs or medications (e.g. caffeine and nicotine), increases in fat-free mass, and possibly the luteal phase of the menstrual cycle can also result in increased rider energy demands (Manore and Thompson, 2015).

The consumption of vitamin and minerals during training and competition to improve athletic performance is common among endurance athletes (Powers et al., 2011; Williams, 2005). Prolonged periods of training and competition place large energy demands on athletes accompanied by a high turnover of vitamins through sweat losses, metabolism, and the musculoskeletal repair process (Knez and Peake, 2010). Consuming sufficient quantities of quality food in the diet to meet these increased needs can be challenging for some athletes, especially in disciplines were weight restrictions apply. Consequently, antioxidant supplementation is a common practice in athletes to prevent exercise-induced oxidative damage and to enhance muscle recovery and performance (Peternelj and Coombes, 2011; Knez and Peake, 2010); however consistent evidence of their efficacy is lacking. Knez and Peake (2010) found the levels of vitamins in male and female ultra-endurance athletes met or exceeded general population dietary reference intakes, with the exception of vitamin D. Across this population, 60% of athletes reported using vitamin supplements, of which vitamin C (97.5%), vitamin E (78.3%), and multivitamins (52.2%) were the most commonly used supplements. Vitamin D deficiency impairs muscular performance, especially in athletes who train or participate in indoor sports (Powers et al., 2011). In athletes who are deficient in vitamin D, supplementation could potentially improve athletic performance but care should be taken as excess levels are toxic (Bartoszewska et al., 2010); however whether athletes should use antioxidant supplements remains an important and highly debated topic. Minerals are inorganic substances essential for a wide variety of metabolic and physiologic processes in the human body including muscle contraction, cardiac rhythm, nerve impulse conduction, oxygen transport, oxidative phosphorylation, enzyme activation, immune functions, antioxidant activity, bone health, and the acid-base balance of the blood (Williams, 2005). Calcium and iron are the two minerals most likely to be deficient in athletes, especially younger and female competitors (Williams, 2005). Osteoporosis can occur due to inadequate calcium intake and / or increased calcium losses; especially at risk in girls and women who can develop the female athlete triad: disordered eating, amenorrhea and osteoporosis (Williams, 2005). Calcium and vitamin D supplementation concurrently are recommended for individuals who are deficient (Gremion et al., 2001). Iron deficiency anemia is more common in athletes and can be related to myoglobin leakage, gastrointestinal losses, sweat losses, or heavy menstrual losses; however the benefits of supplementation depend on the iron status of the individual and is warranted where anemia is present (Williams, 2004). Arguments for and against vitamin and mineral supplementation exist and additional research will be required to firmly establish whether antioxidant supplementation is beneficial or harmful to athletes (Philips et al., 2011). Currently limited scientific evidence exists to recommend antioxidant supplements to athletes and athletes' focus should be on consuming a well-balanced, energetically adequate diet that is rich in antioxidant-containing foods (i.e. whole grains, fruits, vegetables, nuts, and seeds) (Philips et al., 2011).

Hydration status of the endurance rider also needs to be maintained during competition. Increased exercise metabolism can lead to hypo-hydration (2-5% body water loss) through excess heat production and subsequent increased sweating (Nikolaidis et al., 2018). The following equation can be used to determine sweat related water losses during training and competition:

Sweat loss (L) = ¼ Body mass before exercise (kg) – Body mass after exercise (kg) + (Volume of fluid consumed during exercise [L]) – (Urine volume, if any [L])

Sweat rate (L/h) ¼ Sweat loss (L) / Exercise duration (h) (McDermot et al., 2017)

There is evidence to demonstrate that "drinking to thirst" (consuming fluids as thirst dictates (McDermot et al., 2017) during ultra-endurance activities, even under hot ambient conditions, will allow maintenance of proper hydration (Hoffman et al., 2018). However, anecdotal reports suggest endurance riders and their support team will often prioritize horse hydration and potentially forget about their own thirst. Dehydration can result in fluid and electrolytes imbalances which can develop and adversely impact individuals' health and performance. Dehydration can impair exercise performance and contribute to serious heat illness, and hyponatremia can produce grave illness or even death (Sawka et al 2000). Furthermore, care should be taken over what type of fluid replacement drink is utilized; for example commercial sports drinks are not recommended (Hoffman et al., 2018). It is also advisable that the endurance rider estimates the fluid volume they need to consume between water sources to support their thirst as over hydration can also be detrimental to health and developing a hydration protocol (Table 7) is recommended (Casa et al., 2000). Athletes should consider their bodyweight in association with exercise intensity and climatic conditions when developing hydration strategies (Nikolaidis et al., 2018). Using the instinctive thirst mechanism and monitoring bodily parameters such as body weight, urine color, race pace, body temperature, and environmental temperature can help the athlete fine tune their individual hydration needs and avoid complications such as exercise-associated hyponatremia (Vitalie and Retzin, 2019); likewise, how fluids are provided to riders should be considered. Anecdotally many riders will not carry fluids *in situ* on their person when racing, for fear of 'altering the balance' and carrying more weight than necessary. Therefore fluid replacement is grabbed at crew points or riders wait until veterinary gates to take fluid on board, which may not be the most appropriate strategy to maintain optimal hydration. Riders should also be able to recognize the early signs and symptoms of exercise-related hypo-hydration; these include thirst and general discomfort or complaints (approximately 2% body mass deficit), followed by flushed skin, weariness, cramps, and apathy and then more severe symptoms at greater water deficits (more than 2% body mass loss): dizziness, headache, vomiting, nausea, heat sensations on the head or neck, chills, and dyspnea (McDermot et al., 2017). Further investigation to explore optimal strategies and the best methods to ensure endurance riders retain positive hydration status are warranted across all levels of the sport and especially for races in climates which present increased thermal and humidity challenges to the rider.

Table 7: Factors to consider when developing a hydration protocol for athletes based on the National Athletic Trainer's Association Hydration Position Statement (McDermot et al., 2017)

Hydration protocol for athletes	
Monitor indicators of hydration	• Perception of thirst at rest, using scale of 1 [not thirsty at all] to 9 [very very thirsty]) (Note, normally thirst increases when 2% Hypo-hydration is approached and decreases when fluid balance is restored to a loss of less than 2% • Accurately measure body mass using a valid and reliable floor scale pre- and post-training / competition or compare to euhydrated baseline (Note: 3 days consecutive euhydrated baseline measurements are needed to negate the impact of variation related to circadian rhythms) • measure urine concentration (colour or ideally osmolality) and volume using the first morning urination • measure body fat percentage using a trained technician
Pre-race	• Start euhdyrated • Supplement carbohydrates or electrolytes (or both) to rehydration fluids prior to participating in exercise sessions >1 hour or including intense intervals or taking place in extreme environments • supplement fluids containing carbohydrates and electrolytes during extended training bouts and competition • individual assessment of sweat-electrolyte concentrations should occur before considering sodium supplementation • eat a balanced diet • be mindful of the impact of individual cues on hydration status, such as thirst, body weight, urine color, and voiding frequency
Hydration during a race	• maintain hydration and not allow more than a 2% body mass loss • limit body mass losses to less than 2% throughout activity but without gaining weight during exercise • consume enough fluid to approximate personal sweat volume losses and avoid both excessive body fluid losses and overconsumption of fluids • know your personal sweat rate and develop a hydration strategy based on individual needs (i.e. calculate expected fluid losses and ensure sufficient replacement fluid is ingested) • apply short-term revisions to hydration strategies in response to unanticipated events e.g. gastrointestinal upset, discomfort, fluid availability, environmental conditions, fluid type • when individual sweat rates are not known, drinking to thirst during activity represents a safe strategy to prevent overdrinking

After the race	• rapid replacement of fluid post-exercise to restore euhydration, improve recovery and decrease fatigue • Up to 150% of the estimated fluid deficit needs to be consumed to effectively replace fluid losses after exercise over a short recovery period (less than 4 hours) • on an individual basis consider carbohydrate, protein and / or electrolytes in the diet or fluids to assist in restoring fluid balance and muscle glycogen levels, and promote muscle recovery • note: the exact volumes of replacement fluids will depend on solid food ingestion quantity and timing • Caffeine does not compromise rehydration or increase urine output when consumed in small quantities (up to 3 mg/kg) during or after exercise

Endurance riders have to weigh in pre-competition unless competitions apply to the FEI for approval to add sub-categories or eliminate weight allowances prior to the event; acceptable rider weight allowances vary according to race level (refer to Table 5) and include all riding equipment (excluding the bridle) (FEI, 2020a). The mandatory minimum weight limits were introduced by the FEI in 2017 and have been the topic of heated debate in the sport, with some national federations suggested they disadvantage lighter, smaller framed female riders who have to carry weigh to achieve them (Horsetalk, 2020). In contrast heavier, perhaps male riders, may be tempted to diet or fast to attain the allocated weight; a strategy which should be avoided due to the detrimental effect on health and performance. Whilst no studies to date have examined the impact of suboptimal energy and hydration status on the endurance rider, research has explored the impact of nutritional and weight-making practices in professional jockeys in horseracing (Dolan et al., 2011; Martin et al. 2017). Wilson et al. (2014) concluded that rapid weight loss practices had serious adverse effects on jockey mental and physical health, and performance. Endurance riders are recommended to consult with a registered dietitian or nutritionist for a personalized nutrition plan (Thomas et al., 2016) and for individuals where weight loss is necessary, athletes are advised to accomplish it gradually, at a rate of approximately 0.5 kg/week. In order to induce this weight loss, an energy deficit corresponding to about 500 kcal/day will be required. This can be obtained by calorie restriction, increased energy expenditure, or both approaches. Furthermore, such interventions should be programmed to occur in a non- competitive period of the training to minimize loss of performance (Garthe et al., 2011; Rankin, 2002). It is likely that some endurance riders are competing with an inadequate nutritional status for the demands of endurance racing. Alternatively, lightweight riders may need to add and carry additional weight to achieve the standard weight allowances. It is not always possible to attach all the additional weight required to the horse and the use of diving belts and weights is commonplace in lightweight riders. Little is known about the physiological impact of additional weight, especially in a sport where some competitors may be as young as 14 years old or how ‘dead’ weight impacts on the performance of the horse and rider. Going forwards, further research is required to accurately ascertain the nutritional demands of endurance riders both during training and in competition, to enable bespoke nutritional strategies to support the rider as an athlete to be devised.

Psychological demands of endurance riding

Successful endurance performance relies on effective rider decision-making and pacing strategies, and the ability to consistently re-evaluate strategy during race conditions to maximize performance and manage the health and welfare of the horse (Renfree et al., 2014; Tabor and Williams, 2017; Marlin and Williams, 2018a, b). Athletes who do not implement pacing strategies, or who are easily influenced by other competitors' actions, are likely to report premature fatigue, resulting in loss of their own and their horse's performance (Renfree et al., 2014; Brick et al., 2015). Recent studies on pacing strategies utilized in FEI endurance events have suggested that more aggressive, and variable pacing strategies, combined with faster loop one speeds, have been linked to a greater risk of non-completion and withdrawal for metabolic and gait related issues (Bennet and Parkin, 2018; Marlin and Williams, 2018a; Marlin and Williams, 2018b). Throughout a race, endurance riders are also required to make constant tactical changes to their original race strategy; however these changes are often based on the horses' performance and physical monitoring of the equine athlete rather than their own performance (Marlin and Williams, 2018a,b; Renfree et al., 2014).

Any physical activity is defined by the constant flow of three areas of interconnecting physical feedback: perceptible interoceptive feedback (organ-based), kinaesthetic feedback (movement-based) and proprioceptive feedback (spatial cues) (Salmon et al., 2010). Whilst the endurance rider does not directly receive interoceptive feedback from their equine partner, research has suggested that due to the predominantly physical communication between horse and rider, riders often become attuned to their horses' body sensations, becoming highly sensitive to horses' movement proficiency, gait mechanics and speed (Jackman et al., 2015; Jackman et al., 2019; Dashper, 2017). Dashper (2017) refers to this process as kinaesthesia, the complex sensory and motor communication between horse and rider, whilst Jackman et al. (2019) describes a distinct 'feel' of unity and oneness with the horse. This is not dissimilar to the reported connections between individual athletes and sport objects in travel sports during flow states, where it is not unusual to refer to 'the bike and the body as one', blurring the lines between body and sport (Jackson, 1992, 1995; Jackman et al., 2019). Locomotive synchrony is also reported in successful paired sports teams whereby athletes are in tune with their partners' physiological, biomechanical and psychological responses (Jackson, 1992). Therefore endurance riders could utilize kinaesthetic and proprioceptive biofeedback from the horse during a race to monitor pacing strategy within competition.

The management of pacing strategies within a race initiates a high neurocognitive demand for an athlete through consistent cognitive re-evaluation, monitoring of physical effort (combined with the physical effort of the horse in the case of endurance), decision making, risk analysis and continued motivation (McCormick et al., 2015). Smirmaul et al. (2013) suggests there are only two psychological determinants that directly influence endurance performance: perception of effort and potential motivation. Perception of effort is defined as the conscious recognition of the sensation of exercise, the appraisal of significant increases in intensity and duration resulting in a subjective sense of strain, which is detrimental to endurance performance (Salmon et al., 2010). Whilst research has reported that perception of effort increases exponentially around the onset of blood lactate accumulation in human endurance athletes suggesting it is based on purely physical feedback (Salmon et al., 2010), there is evidence that perception of effort is independent from peripheral afferent feedback loops (Smirmaul et al., 2013). The psychobiological model suggests that the perception of bio-feedback and perception of effort are two separate neurological mechanisms (Smirmaul et al., 2013). Therefore athlete perception of effort in endurance sports is more likely to be hindered by mental fatigue affecting the central processing of sensory input in the anterior cingulate cortex (ACC) region of the brain (Macora et al., 2009).

Mental fatigue is defined as a psychobiological state caused by prolonged periods of demanding cognitive activity, such as the continual reassessment of pacing strategies and biofeedback analysis seen within endurance sports (Macora et al., 2009). Mental fatigue has been reported to result in increases in perception of effort during a race, resulting in decreased performance (McCormick et al., 2015). In addition, athletes are likely to decrease engagement with harder physical tasks when mentally fatigued, such as within the latter stages of endurance races if an appropriate fitness strategy has not be implemented, with can limit performance potential (Macora et al., 2009). For equine endurance events, similarly to ultramarathons or phase looped endurance sports, there is a likelihood that during the course of the event, riders will experience time away from other competitors. Research suggests that the presence of others during endurance sport increases drive and arousal, and reliance on dominant behavior and motor skill patterns, making the completion of the sport ‘feel’ easier to an athlete, reducing mental fatigue levels (Spence et al. 1956a; Spence et al. 1956b; Bishop et al., 2001; Strauss 2002). Without the presence of competitors, endurance riders may experience higher levels of mental fatigue and therefore decreased motivation to continue (Spence et al. 1956a; Spence et al. 1956b; Bishop et al., 2001; Strauss 2002), which could negatively influence their ability to complete the race. Within equestrian endurance, the unique biofeedback mechanisms from horse to rider could result in higher levels of cognitive demand and mental fatigue (McCormick et al., 2015), combined with competition isolation, resulting in increased perception of effort in endurance riders through personal mental fatigue rather than based on biosensory input from the horse causing them to alter speeds or strategy incorrectly mid-race.

Potential motivation, based on Motivational Intensity Theory (Brehm, 1989), is determined as the greatest amount of effort an athlete will use to satisfy their motives (McCormick et al., 2015). When there is a known endpoint to endurance exercise, i.e. closed loop tasks, such as completing loops within an endurance competition, athletes are likely to be more motivated to complete, offsetting any potential negative biofeedback, such as muscle soreness or pain (Smirmaul et al., 2013; Renfree et al., 2014). However, at lower intensity exercise, increased motivation associated with a perceived endpoint of exercise can result in athletes underestimating physical exertion, resulting in them starting races too quickly, and reaching peak performance too early within a race (Hall et al., 2005; Renfree and St. Clair Gibson, 2013). This phenomena has been reported in equine endurance research, with Bennett and Parkin (2018) reporting that faster riding speeds in loops one and two were associated with detrimental outcomes, suggesting that endurance riders are at increased risk of underestimating horses’ physical exertion.

Associative and dissociative strategies are widely utilized by endurance athletes, alongside psychological skills training, at all levels to attempt to enhance performance (McCormick et al., 2015). Associative strategies, often implemented by elite athletes, require constant monitoring of body sensations and the use of biofeedback to regulate or adjust pace (McCormick et al., 2015). Dissociative strategies are more commonly seen in non-elite endurance athletes, who use internal or external coping mechanisms, such as daydreaming, music or scenery, to direct attention away from unpleasant sensations

(Brick et al., 2014; McCormick et al., 2015). Whilst dissociation is more commonly reported to be correlated to a decrease in perceived effort, the limited engagement with biofeedback can result in errors in early race pacing strategies leading to poor performance (Renfree et al., 2014). For endurance riders who do not directly experience those unpleasant physical sensations that may limit equine performance resulting in metabolic or gait eliminations, the risk of utilizing dissociative strategies to avoid reflection on personal fatigue may be seen, resulting in failure to identify the horses speed during loops which could negatively impact performance (Bennet and Parkin, 2018; Marlin and Williams, 2018a,b). Psychological recommendations for successful performance in equestrian endurance would include riders using associative strategies, such as monitoring equine biofeedback through pacing and equine heart rate (Marlin and Williams, 2018a; Marlin and Williams, 2018b), to regulate and adjust pace during their race whilst aiming to decrease reliance on distraction techniques during their ride. Within equestrian endurance, the use of monitoring devices for pacing, speed and physiological demand are permitted under FEI rules (FEI, 2020a), which should further allow riders to focus more on associative strategies. Further research should also explore the current use of associative and dissociative strategies in FEI endurance riders and the implications of psychological status and fatigue on race tactics including pacing, particularly related to loop one speed.

Conclusion

To date, the core focus in endurance riding has been on how the rider and their associated support team execute their duty of care and manage the health and welfare of the equine athlete with less emphasis placed on the rider. Successful endurance riding requires an effective partnership to be established between horse and rider. Within this partnership, adequate rider health and fitness are key to optimal decision-making in respect of not only their horse in training and competition, but just as importantly with respect to how they manage themselves as an athlete. In the absence of discipline specific research, the aspiring endurance athlete should take a more holistic approach, managing their own performance by adopting training and competition strategies used effectively to date by ultra-endurance athletes to maximize their own and their horse’s performance. Targeted management for superior rider performance can underpin more effective decision-making promoting ethical equitation practices and optimizing competition performance. The responsible and competitive endurance rider needs to consider how they prepare themselves adequately for participation in the sport. This should include engaging in appropriate physiological training for fitness and strength and conditioning. Alongside planning nutritional strategies to support rider performance in training and within the pre-, peri- and post-competition periods, to promote superior physical and cognitive performance, and to prevent injury. Applying an evidence informed approach to self-management by the endurance athlete (rider) will ultimately support horse and rider partnerships to achieve to their optimal capacity, whilst maximizing both parties physical and psychological wellbeing.

Despite the popularity of endurance riding, endurance riders represent an under-researched demographic within equestrianism. This presents a fundamental issue for riders participating in the sport who wish to engage with performance analysis and evidence informed training and competition strategies, to improve their performance. We would therefore like to issue an edict to the sector, for industry and researchers to come together and rectify this situation through a planned programme of applied research to support the endurance rider in achieving to their full potential, which should, by association, have a positive impact on their equine partners.

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